

Synchrotron-radiation based micro-computed tomography applied to the study of dinosaur eggshells from the Lourinhã Formation (Portugal)

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The Lourinhã Formation exposed in the area around Lourinhã, central west Portugal, is very rich in fossils of dinosaurs of the Late Jurassic. The collections of the Museum of Lourinhã provide new information for the evolutionary history of development. However, the potential of this material has not been fully realized because of reliance on traditional, non-destructive methods that allow analysis of exposed surfaces only, and destructive methods that preserve only a single two-dimensional view of the interior of the specimen.

The study of fossilized eggshells can provide precious information about the organisms that laid the eggs and the depositional environment in which eggshell has been preserved. Although the eggshells fragments are subject to alteration, associated with some processes of transport and destruction due to its physical and chemical composition, unique features can be preserved. Their internal structure is often still marked, despite mineralogical alteration. The histostructure of the eggshell provides information with biological and paleoenvironmental implications. For example, the eggshell pore pattern is associated with gas exchange ratios between nest environment and embryo. Moreover, the study of the porosity of the shell can provide valuable information about the level of humidity of the area where the egg was laid. Therefore, it is very important to gain insight into the pore structure of the fossilized eggshells through non-destructive techniques.

The eggshell fragments analysed in this work have been collected in three different sites of the Lourinhã Formation, namely: Peralta, Paimogo and Porto de Barcas. The eggshell type detected in Paimogo, of thickness of about 0.92 mm [1], is ascribed to the theropod *Lourinhanosaurus antunesi*. This specimen belongs to the nest found in Paimogo, which contains embryos. The external morphology and the size of the eggshells of Paimogo and Peralta sites are comparable. The Peralta site is less than 800 m from the type locality of *Lourinhanosaurus* and within the same stratigraphic range. They can be from the same species or a closely related taxon. However, more details are required to draw final conclusions. The eggshell fragment from Porto de Barcas site has been detached from the clutch of approximately 65 cm diameter that was found south of Porto de Barcas presenting bones and teeth of a saurischian dinosaur. The eggshell fragments collected in this site exhibit a thickness of about 1.23 mm and a different type of morphology.

The synchrotron radiation based micro-computed tomography (SR μ CT) studies have been performed at the beamline HARWI II at the storage ring DORIS III located at DESY in Hamburg, Germany. The technical details of the beamline have been published by Beckmann et al. [2,3] and in the book by Reimers, Pyzalla, Schreyer, and Clemens [4]. Recent information can be found in J. Herzen Ph.D. thesis work [5]. The tomography set-up consists of a high precision rotation stage, which allows us to mount the sample hanging from above, and an X-ray detector. In the detector a fluorescent screen converts the X-rays into visible light that is magnified by a lens and detected by a CCD camera. The specimens were imaged by microtomography in absorption mode with photon energy of 37 keV. For acquiring the X-ray attenuation projections the sample was rotated between 0 and 180° in equidistant steps of 0.25°.

The first data recorded for eggshells collected in the Lourinhã Formation, Porto de Barcas site, is shown in Figure 1. The effective pixel size corresponds to 6.4 μm , which allows a direct, non-destructive visualization of the morphology of the pores and their connectivity in the eggshell fragments, providing information that is either exceedingly difficult or impossible to obtain by traditional methods based on section cutting.

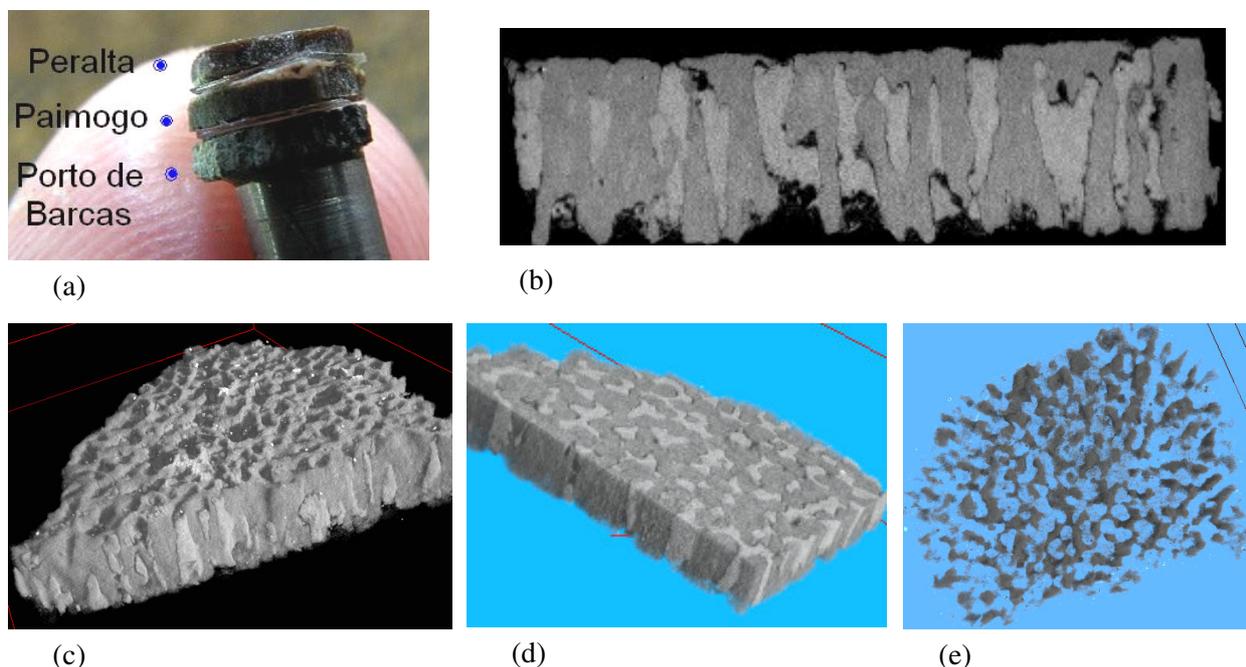


Figure 1. Eggshell fragments collected in three different localities of the Lourinhã Formation (Peralta, Paimogo and Porto de Barcas): (a) photograph of the eggshell pieces mounted on the sample holder used for SR μ CT; (b) a microtomographic slice through the eggshell type of the locality of Porto de Barcas; (c) a three-dimensional image of the complete sample of the locality of Porto de Barcas; (d) sectioning of the three-dimensional image of the sample of figure 1c providing information about pore connectivity in the eggshells; (e) pore canals run through the shell which permit gas exchange between the embryo and atmosphere.

Summary

The high quality data show that SR μ CT is an extremely useful technique for non-destructive imaging of the morphology of dinosaur eggshells. It proved to be very effective for the acquisition of three-dimensional images with high spatial resolution, revealing otherwise inaccessible details such as the three-dimensional internal morphology of pore. The visualization of the connectivity of the pores is also a plus for a complete and accurate characterization of this precious material found in the Lourinhã Formation, in Portugal. The data collected at the beam line HARWI II is now in evaluation and a detailed description of the eggshells and a comparison between the results obtained for the eggshells of the different localities will be published elsewhere.

References

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